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TIER 2 AND 3 SUBSURFACE VAPOR INTRUSION SCREENING AT THE COMMONWEALTH OIL AND REFINING COMPANY SITE PEÑUELAS, PUERTO RICO

Prepared for:

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1.0 Site Description

The Commonwealth Oil and Refining Company Incorporated (CORCO) is located at Route 127, Municipio de Peñuelas, Puerto Rico (site). The CORCO facility has been divided into separate areas in previous investigations based on facility operations and the nature of impact. The separate areas of the CORCO facility are displayed in Figure A-1. The CORCO main site includes the current tank farm and former refinery area. This portion of the site consists of active and inactive product and water storage tanks, former refinery units, warehouses, and office buildings including the main administration building, which is the focus of this investigation. The administration building is located in the southeast portion of the main site, just north of Route 127. The CORCO administration building (main office) location is depicted in Figure A-2.

The February 16, 2005 Letter Report-Environmental Indicators prepared by NewFields (NewFields, 2005) indicates that a light non-aqueous phase liquid (LNAPL) plume exists under the main site. The petroleum LNAPL plume thickness at the main site has been interpolated to range from approximately 1.0E-05 feet to 12 .0 feet across the main site using ground water and LNAPL gauging data from November 2003. NewFields has estimated that millions of gallons of product have been removed from the site monitoring wells utilizing active skimmers and vacuum extraction events from 1994 to 2003. The LNAPL recovery system is currently operating, and will continue to operate into the foreseeable future.

In July of 2005 five additional monitoring wells were installed in the immediate area of the administration building. The free product plume is estimated to be only 0.035 feet thick in this area. The administration building is a one-story building, approximately 140 feet by 50 feet and consists of a slab on grade construction with footers that extend to approximately four (4) feet in the native soils. There is no basement or crawl space. The slab on grade consists of four (4) inch thick concrete reinforced with eight (8) gauge six (6) by six (6) inch wire mesh.

2.0 Scope of Work

The scope of work for this evaluation consists of the preparation of a Combined Tier 2 and 3 Subsurface Vapor Intrusion Screening (Vapor Intrusion Screening) for the administration building at the CORCO facility. The Vapor Intrusion Screening is conducted in accordance with the United States Environmental Protection Agency (USEPA) Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Ground Water and Soils Guidance (USEPA, 2002). The questions from the Tier 1 (Primary Screening), Tier 2 (Secondary Screening), and Tier 3 (Site-Specific Screening) are listed in the ensuing sections followed by the appropriate response.

Data for this evaluation was limited to existing ground water concentration and light non-aqueous phase liquid (LNAPL) information from previous investigations. Additional soil, ground water, soil gas, and indoor air sampling were not included in this assessment.

Two (2) models were used to evaluate the vapor intrusion pathway in this report. This includes the Johnson and Ettinger Screening Level model and the USEPA Non-Aqueous Phase Liquid (NAPL) ADV model conducted in the Tier 2 and Tier 3 Screening, respectively.

Based on the results of this Vapor Intrusion Screening, action levels were determined for groundwater and soil gas vapor beneath the administration building foundation in the Tier 2 Screening. Indoor air concentrations were also modeled using the NAPL-ADV model.

3.0 Vapor Intrusion Evaluation Process

The Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Ground Water and Soils Guidance (USEPA, 2002) consists of Tier 1-Primary Screening, Tier 2-Secondary Screening, and Tier 3-Site-Specific Pathway Assessment. The flow diagram consists of a series of question which guide the decision making process with regards to vapor intrusion. The questions provided in USEPA, 2002 are presented below for each tier.

3.1 Tier 1 Primary Screening

Q1: Are chemicals of sufficient volatility and toxicity known or reasonably expected to be present in the subsurface?

<u>A1: Yes.</u> Expected chemicals were selected based solely on detectable concentrations noted in ground water from data points PD-15 and PD-16, which were the closest available data points for evaluation at the time of this assessment.

Table 3-1: Expected Chemicals of Sufficient Toxicity and Volatility.

CAS No.	Chemical	Is Chemical Sufficiently Toxic?[1]	Is Chemical Sufficiently Volatile?[2]	Does Chemical Meet Criteria for Toxicity and Volatility?
71432	Benzene	Yes	Yes	Yes
108883	Toluene	Yes	Yes	Yes
100414	Ethylbenzene	Yes	Yes	Yes
95476	o-Xylene	Yes	Yes	Yes
108383	m-Xylene	Yes	Yes	Yes
106423	p-Xylene	Yes	Yes	Yes

1. A chemical is considered sufficiently toxic if the vapor concentration of the pure component poses and incremental lifetime cancer risk greater than 10^{-6} or a non-cancer hazard index greater than 1 (Appendix D, USEPA, 2002).
2. A chemical is considered sufficiently volatile if its Henry's Law Constant is 1×10^{-5} atm-m^3/mol or greater (USEPA, 1991).

Q2: Are currently (or potentially) inhabited buildings or areas of concern under future development scenarios located near subsurface contaminants found in Table 3-1?

<u>A2: Yes.</u> The building evaluated for this assessment is limited to the CORCO administration building. The location of this building is documented in Appendix A. Building construction diagrams are located in Appendix B.

Q3: Does evidence suggest immediate action may be warranted to mitigate current risks?

<u>A3: No.</u> The qualitative criteria considered sufficient to indicate the need for immediate actions such as odors indicative of petroleum products, physiological effects reported by occupants indicative of petroleum chemical inhalation, building flooding, or measured likely explosive or acutely toxic concentrations of vapors were measured.

3.2 Tier 2 Secondary Screening

Q4(a): Are indoor air quality data available?

A4(a): No. *(If no, proceed to Subsurface Source Identification-Question 4(c)).*

Q4(c): Is there any potential for contamination (source of vapors) in the unsaturated zone soil at any depth above the water table?

A4(c): No. *(if no, proceed with Groundwater Assessment-Question 4(d)).* Although potential for contamination in the unsaturated zone above the water exists in the form of soil gas, no soil gas data is available, and was not procured as part of this evaluation. Therefore, the source of soil vapors for this evaluation is considered to be from the dissolved phase in groundwater and from LNAPL sources.

Q4(d): Do measured or reasonably estimated groundwater concentrations exceed the generic target media-specific concentrations given in Tables 2(a), 2(b), or 2(c)?

A4(d): Yes. Table 3-2 lists the generic target concentrations for indoor air and groundwater noted in Table 2 of USEPA, 2002. The target concentrations were based on a $1x10^{-5}$ cancer risk. Soil gas data were not available for this assessment *(If soil gas data are available, proceed to Soil Gas Assessment, otherwise proceed to Question 5).*

Table 3-2: Generic Target Indoor Air and Groundwater Concentrations.[1]

CAS No.	Chemical	Target Indoor Air Concentration[1] (ug/m^3)	Generic Target Groundwater Concentration[2] (ug/L)	Basis of Target Concentration C=Cancer Risk NC=Non-Cancer Risk
71432	Benzene	3.1E+00	1.4E+01	C
108883	Toluene	4.0E+02	1.5E+03	NC
100414	Ethylbenzene	2.2E+01	7.0E+02*	C
95476	o-Xylene	7.0E+03	3.3E+04	NC
108383	m-Xylene	7.0E+03	2.3E+04	NC
106423	p-Xylene	7.0E+03	2.2E+04	NC

1. Target indoor air concentration to satisfy both the prescribed risk level and the target hazard index ($R=10^{-5}$, HI=1).
2. Target groundwater concentration corresponding to target indoor air concentration where the soil gas to indoor air attenuation factor = 0.001 and partitioning across the water table obeys Henry's Law.

* The target ground water concentration is the MCL.

** Target soil gas concentration exceeds maximum possible vapor concentration (pathway incomplete).

Q5(a): Do ground water and/or soil gas concentrations for any constituents of potential concern exceed target media-specific concentrations by a factor greater than 50?

A5(a): Yes. Table 3-3 compares the average groundwater concentrations from the July 26, 2005 sampling event of MSEI-MW-1 through MW-4 to the generic target groundwater concentrations noted in Table 2 of USEPA, 2002. *(If yes, proceed to Site-Specific Assessment-Question 6).*

Table 3-3: Site Maximum Groundwater Concentrations Compared to Generic Target Concentrations.			
CAS No.	**Chemical**	**Generic Target Groundwater Concentration (ug/L)**	**Average Groundwater Concentration beneath Administration Building[1] (ug/L)**
71432	Benzene	1.4E+01	3.3E+04
108883	Toluene	1.5E+03	1.825E+04
100414	Ethylbenzene	7.0E+02*	3.5E+04
95476	o-Xylene	3.3E+04	Total Xylenes = 1.2E+05
108383	m-Xylene	2.3E+04	
106423	p-Xylene	2.2E+04	

1. Average groundwater concentrations from MSEI-MW-1 through 4, July 26, 2005.
* The target ground water concentration is the MCL.

Although average groundwater concentrations from the July 26, 2005 sampling event of MSEI-MW-1 through MW-4 exceeded the generic target concentrations greater than a factor of 50, the appropriate vapor attenuation factor for the ground water to indoor air and soil vapor to indoor air pathways were selected based on the depth to groundwater from the base of the foundation and the appropriate soil type.

The vapor attenuation factors were selected from the Table 3a and 3b from USEPA, 2002. The assumed soil type is loam with an approximate depth to groundwater of 36 feet or 11 meters. Based on the site-specific information, the groundwater to indoor air vapor attenuation factor is 2.0E-04.

Table 3-4 compares the groundwater screening levels with the site-specific vapor attenuation factor to the assumed average groundwater concentrations beneath the administration building.

Table 3-4: Site Maximum Groundwater Concentrations Compared to Groundwater to Indoor Air Screening Levels for Scenario-Specific Vapor Attenuation Factors.			
CAS No.	**Chemical**	**Groundwater Screening Levels (ug/L)**	**Average Groundwater Concentration beneath Administration Building (ug/L)**
71432	Benzene	6.9E+01	3.3E+04
108883	Toluene	7.4E+03	1.825E+04
100414	Ethylbenzene	7.0E+02	3.5E+04
95476	o-Xylene	1.6E+05	Total Xylenes = 1.2E+05
108383	m-Xylene	1.2E+05	
106423	p-Xylene	1.1E+05	

Table 3-5 lists the soil vapor screening levels with the site-specific vapor attenuation factor. There was no known soil vapor data available for comparison. The soil vapor to indoor air attenuation factor (2.0E-03) assumes that the soil vapor sources are directly below the slab on grade basement.

Table 3-5: Soil Gas Levels for Scenario-Specific Vapor Attenuation Factors.		
CAS No.	**Chemical**	**Soil Vapor Screening Levels (ug/m^3)**
71432	Benzene	1.6E+03
108883	Toluene	2.0E+05
100414	Ethylbenzene	1.1E+04
95476	o-Xylene	3.5E+06
108383	m-Xylene	3.5E+06
106423	p-Xylene	3.5E+06

The average assumed concentrations of BTEX in ground water exceed the generic groundwater to indoor air target levels and the groundwater to indoor air screening levels based on the appropriate vapor attenuation factor. Soil vapor screening levels were presented for the appropriate attenuation factor. However, soil vapor data was not available for comparison to the screening levels.

3.2.1 Johnson and Ettinger Model

The Primary Screening did not exclude the existence of a complete vapor intrusion pathway. The average assumed ground water concentrations from data points MSEI-MW-1 through MW-4 were assumed to be representative ground water concentrations beneath the administration building.

The Johnson and Ettinger model was used to calculate target groundwater concentrations that would result in the generic target indoor air concentration for each chemical. The Johnson and Ettinger Screening Level Implementation of the Vapor Intrusion Model from the USEPA On-Line Tools for Site Assessment Calculation was used in this evaluation. This implementation of the Johnson and Ettinger model replicates the implementation that the USEPA Office of Solid Waste and Emergency Response (OSWER) used in developing the USEPA Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Ground Water and Soils Guidance.

It is assumed that LNAPL is present underneath the administration building. The Johnson and Ettinger model does not account for vapor intrusion from LNAPL sources. This was done to conservatively calculate groundwater target levels directly under the administration building after the removal of the LNAPL, or after verification that LNAPL is not present. The Johnson and Ettinger model was conducted on each potential chemical assuming a soil type of loam, average depth to groundwater of 23.75 feet with a 2 foot range of fluctuation, average groundwater temperature of 77 degrees Fahrenheit (25 degrees Celsius), and a slab on grade foundation type.

Groundwater concentrations were entered until the generic target indoor air concentration was calculated by the model. The resulting groundwater concentrations are considered the maximum groundwater concentrations that can exist beneath the administration building that will be protective of the groundwater to indoor air vapor intrusion pathway. The input parameters and results for each chemical simulation are presented in Appendix C. Results of the groundwater to indoor air vapor intrusion modeling are presented in Table 3-6.

Results of the modeling indicate that the average groundwater concentrations from the July 26, 2005 sampling event of MSEI-MW-1 through MW-4 are in excess of the estimated groundwater concentrations that will result in indoor air concentrations below the generic target levels.

Table 3-6: Site Maximum Groundwater Concentrations Compared to Modeled Acceptable Groundwater Concentrations.

CAS No.	Chemical	Maximum Allowable Groundwater Concentration[1] (ug/L)	Average Groundwater Concentration beneath Administration Building (ug/L)
71432	Benzene	1.4E+02	3.3E+04
108883	Toluene	1.55E+04	1.825E+04
100414	Ethylbenzene	8.5E+02	3.5E+04
95476	o-Xylene	3.4E+05	Total Xylenes = 1.2E+05
108383	m-Xylene	3.05E+05	
106423	p-Xylene	2.67E+05	

1. Maximum allowable groundwater concentration is based solely on the screening level Johnson and Ettinger model with the assumptions presented in Appendix C for the vapor intrusion to indoor air pathway only.

3.3 Tier 3 Site-Specific Assessment

The Primary and Secondary Screening did not exclude the existence of a complete vapor intrusion pathway. The Johnson and Ettinger model was used to calculate target groundwater concentrations that would result in the generic target indoor air concentration for each chemical. Results of the Johnson and Ettinger model conducted in the Tier 2 Secondary Screening indicated that the maximum allowable concentration for each evaluated chemical that will result acceptable indoor air concentrations were less than assumed average concentration beneath the administration building. However, the Johnson and Ettinger model does not account for LNAPL as sources of indoor air impact through volatilization and intrusion.

3.3.1 USEPA NAPL-ADV Model

Since it is assumed that LNAPL is present underneath the administration building, the USEPA Non-Aqueous Phase Liquids (NAPL) ADV model was used to evaluate the intrusion of vapors from the assumed LNAPL source. The NAPL-ADV model (USEPA, 2003) is specifically designed to handle non-aqueous phase liquids or solids in soils. Up to ten (10) contaminants may be selected to compose the mixture. Soil concentrations are entered into the input module of the model. The model then determines if saturation conditions exist based on the input, which simulates the NAPL source.

The residual phase theory, ancillary calculations, and building concentration calculations are presented in the *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings* (USEPA, 2003). The model assumes that steady state conditions have been achieved and the subsurface vapor plume has reached its maximum concentration directly underneath the basement surface.

The input parameters and results of the NAPL-ADV model are presented in Appendix D. The input concentrations for each of the selected chemicals were the maximum detected BTEX concentration in groundwater from the July 26, 2005 sampling event from MSEI-MW-1 through MW-4. The depth to subsurface sources and soil properties were estimated based on the boring logs from MSEI-MW-1 through MW-5. The contaminant source was assumed to exist under the entire administration building. Results of the NAPL-ADV model are presented in Table 3-7.

Table 3-7: NAPL-ADV Model Results

CAS No.	Chemical	Time Averaged Building Concentration (ug/m^3)	Incremental Cancer Risk (unitless)
71432	Benzene	3.75E+00	7.2E-06
108883	Toluene	1.22E+00	NA
100414	Ethylbenzene	4.32E+00	1.2E-06
95476	o-Xylene	1.34E+01	NA
108383	m-Xylene	1.34E+01	NA
106423	p-Xylene	1.34E+01	NA

Results of the NAPL-ADV indicate that the Incremental Cancer Risk is less than 1E-05. The time averaged building concentrations are compared to the generic target indoor air concentrations in Table 3-8.

Table 3-8: NAPL-ADV Model Time Averaged building Concentrations Compared to Generic Target Indoor Air Concentrations.

CAS No.	Chemical	Target Indoor Air Concentration[1] (ug/m^3)	Time Averaged Building Concentration[2] (ug/m^3)
71432	Benzene	3.1E+00	3.75E+00
108883	Toluene	4.0E+02	1.22E+00
100414	Ethylbenzene	2.2E+01	4.32E+00
95476	o-Xylene	7.0E+03	1.34E+01
108383	m-Xylene	7.0E+03	1.34E+01
106423	p-Xylene	7.0E+03	1.34E+01

1. Target indoor air concentration to satisfy both the prescribed risk level and the target hazard index (R=10^{-5}, HI=1).
2. Time averaged building concentration from NAPL-ADV model.

BOLD Indicates modeled indoor air concentration in excess of target indoor air concentration.

Modeled indoor air concentrations of BTEX are below the target indoor air concentrations, with the exception of benzene. Since benzene's modeled indoor air concentration is close to the generic target indoor air concentration, and the target risk is 7.2E-06, benzene concentrations should not pose an unacceptable indoor air risk to workers in a commercial scenario. All other modeled indoor air chemical concentrations are below their respective target concentration and should not pose an unacceptable indoor air risk to workers in a commercial scenario.

4.0 Vapor Intrusion Conclusions & Recommendations

4.1 Conclusions

Results of the Tier 1, 2, and 3 vapor intrusion screening yielded the following results:

- The maximum allowable groundwater concentrations developed using the Johnson and Ettinger model under the Tier 2 Secondary Screening yielded maximum allowable groundwater concentrations lower than the average groundwater concentrations from MSEI-MW-1 through MW-4 from the July 26, 2005 sampling event, which are assumed to be representative of conditions beneath the administration building.
- The model predicted time averaged building concentrations from the USEPA NAPL-ADV model are greater than the target indoor air concentrations with the exception of benzene.
- The NAPL-ADV model predicted an indoor air concentration of 3.75 ug/m^3 and a 7.2+06 cancer risk for the chemicals evaluated.
- Soil vapor screening levels were determined from the corresponding site-specific vapor attenuation factor.

Results of the Johnson and Ettinger model, USEPA NAPL-ADV model, and the soil vapor screening levels for the corresponding vapor attenuation factor are summarized in Table 4-1.

Table 4-1: Summary of Modeled Concentrations in Groundwater, Indoor Air, and Derived Soil Vapor Screening Levels.

CAS No.	Chemical	Maximum Allowable Groundwater Concentration[1] (ug/L)	Time Averaged Building Concentration[2] (ug/m^3)	Soil Vapor Screening Levels[3] (ug/m^3)
71432	Benzene	1.4E+02	3.75E+00	1.6E+03
108883	Toluene	1.55E+04	1.22E+00	2.0E+05
100414	Ethylbenzene	8.5E+02	4.32E+00	1.1E+04
95476	o-Xylene	3.4E+05	1.34E+01	3.5E+06
108383	m-Xylene	3.05E+05	1.34E+01	3.5E+06
106423	p-Xylene	2.67E+05	1.34E+01	3.5E+06

1. Maximum allowable groundwater concentration that will result in indoor air vapor concentrations protective of generic target indoor air concentrations derived from the Johnson and Ettinger model (Appendix C).
2. Time averaged building concentration from NAPL-ADV model (Appendix D).
3. Soil vapor screening levels derived in the secondary screening using a site-specific vapor attenuation factor.

5.0 Limitations

5.1 Uncertainty

A list and description of the uncertainties in this evaluation and the relationship between the exposure and toxicity are presented herein. Quantifying additional uncertainty due to the lack of knowledge or variability has not been included. A list and description of the uncertainties are presented in the ensuing pages.

- The available concentrations measured from the ground water samples taken at the site are assumed to be accurate.

- This report is based solely on the data provided to On-Site Environmental, Inc. (OSE) by CORCO. All chemical-specific input parameters used in the models described herein were taken directly from, or assumed from the literature based on the data provided to OSE. The data provided to OSE from CORCO was assumed to be complete and accurate. If further site-specific information is gathered, or becomes available by any other means, the assumptions, models, risk characterization and assessment may need to be re-evaluated.

- This vapor intrusion evaluation is based on the data collected from the nearest known data points. These concentrations and LNAPL data are assumed to be representative of the area beneath the CORCO administration building. If additional data is collected, or existing data becomes available, additional assessment or recalculations may be necessary.

- This vapor intrusion evaluation did not include any indoor air or soil gas sampling, or the collected of any new data for the specific use of vapor to indoor air pathway evaluation. This report makes no claims as to the actual quality of indoor air in the CORCO administration building with respect to any subsurface vapor intrusion. This report only identifies target concentrations in ground water and soil gas that would be protective of target indoor air concentrations in the administration building.

- This vapor intrusion evaluation is limited to the chemicals identified herein. No evaluation of any other chemicals or compounds that currently exist, have historically existed, or have the potential to be present were identified or evaluated.

- This indoor air vapor intrusion screening is limited to the CORCO administration building only.

6.0 References

CSA Group (CSA). November 2000. *CORCO Phase II Environmental Site Assessment*

NewFields. February 16, 2005. *Letter Report – Environmental Indicators.*

NewFields. April 2004. *Historical Free Product Evaluation.*

USEPA. 2002. *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Ground Water and Soils Guidance.*

USEPA. *Evaluating Vapor Intrusion Using the Johnson and Ettinger Model* http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

USEPA. June 19, 2003. *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.*

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The owner/operator acknowledges that subsurface conditions may vary from those encountered at the locations where borings, surveys, samples, or explorations are made. The data, interpretations, and recommendations of On- Site Environmental, Inc. may be based solely on the information available to us. On- Site Environmental, Inc. assumes that the data that has been obtained and/or provided through previous investigations represents the true conditions of the site. It is understood by the owner/operator that some of the information in this report may be second hand. It will be the responsibility of the owner/operator to review the report for accuracy. On- Site Environmental, Inc. will be responsible for its data, interpretations, and representations, but will not be responsible for the data provided to us or for the interpretation of the information by others.

The evaluated petroleum constituents were assumed to be the only contaminants on this site. If active refining or other operations currently exist that pose a material threat of release then a currently on-going and/or future release may change subsurface data which may invalidate the conclusions of this report. On- Site Environmental, Inc. makes no claims or warrantees regarding United States EPA action levels or standards and their respective or cumulative effects on the human body. Nothing in this document should be interpreted as an expert opinion regarding human health or degree of safety due to the presence of contaminants at and/or emanating from the site. Moreover, this report does not include an ecological risk assessment.

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Appendix A - Figures

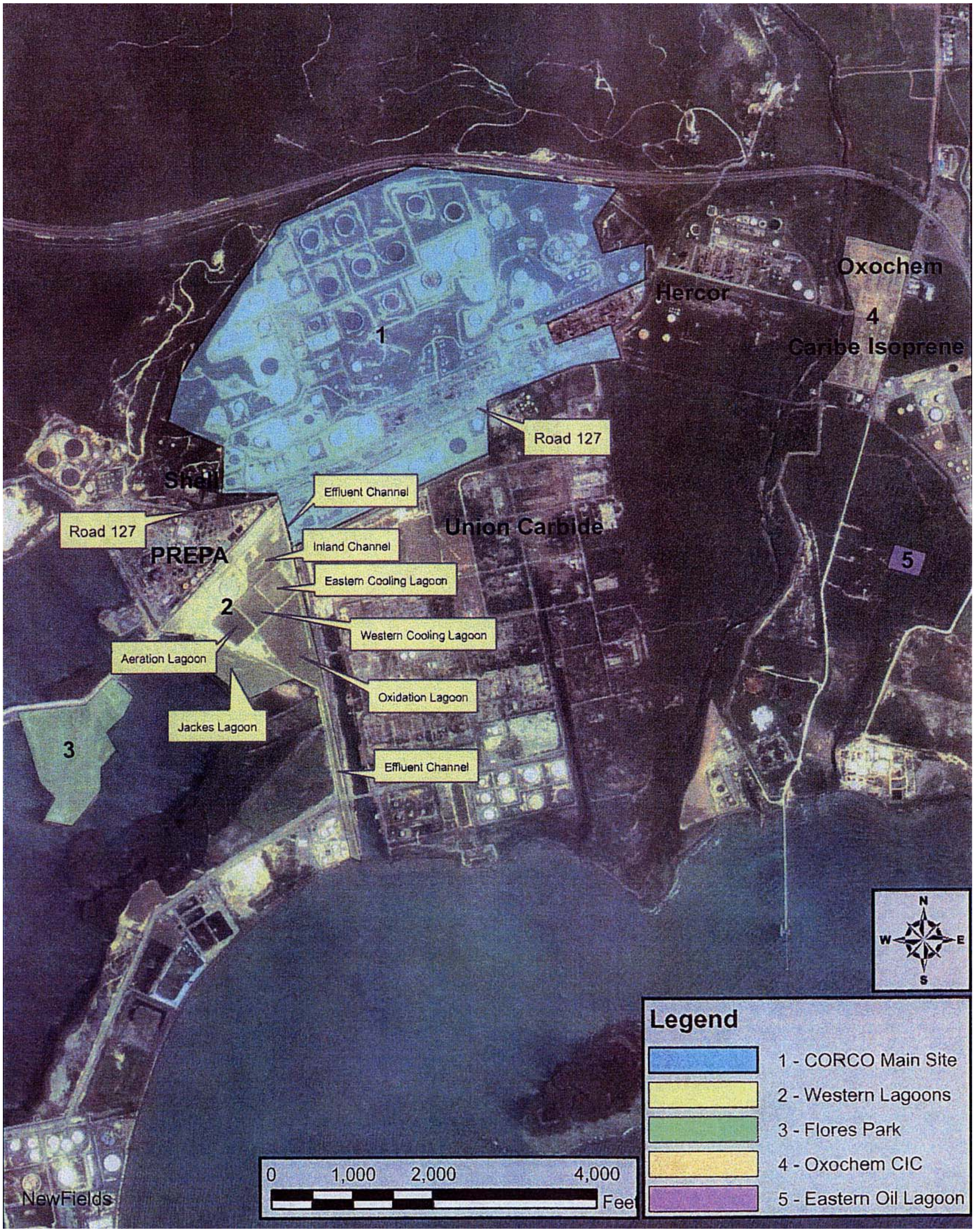

Figure A-1: Site Location Map (Area1)

Figure A-2: Monitoring Well Locations (MSEI-1 through MW-5)

Appendix B - Administration Building Diagrams

Appendix C - Data Tables and Boring Logs

Table C-1: Product Thickness and BTEX in Groundwater

Sample ID	Date	Depth to Water (feet)	Depth to Product (feet)	Product Thickness (feet)	Benzene (ppm)	Toluene (ppm)	Ethylbenzene (ppm)	Xylenes (ppm)
MSEI-MW-1	7/26/05	20.63	20.61	0.02	11	12	79	245
MSEI-MW-2	7/26/05	23.45	23.40	0.05	69	22	36	130
MSEI-MW-3	7/26/05	22.46	NA	NA	30	20	12	47
MSEI-MW-4	7/26/05	22.19	NA	NA	22	19	13	57
MSEI-MW-5	7/26/05	30.03	NA	NA	NS	NS	NS	NS

Appendix D - Johnson and Ettinger Model

INDOOR AIR SIMULATION RESULTS - BENZENE
Screening-Level Johnson and Ettinger Model

Site Name: CORCO

Report Generated From: http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

Type of sample: GROUND WATER Concentration = 140[ppb-water]

Depth to ground water table: 23.75ft +/- 2ft

Average soil/ground water temperature: 77F

CHEMICAL PROPERTIES

Chemical of Concern: Benzene CAS Number: 71432

Molecular Weight: 78.11 [g/mole] Henrys Constant: 0.2263008 [unitless]

Diffusivity in Air: 8.800e-2 [cm^2/sec] Diffusivity in Water: 9.800e-6 [cm^2/sec]

Unit Risk Factor: 0.0000078 [$(\mu g/m^3)^{-1}$] Reference Concentration: 0 [mg/m^3]

SOIL PROPERTIES

Soil Type: Loam Total Porosity: 0.399

Unsaturated Zone Moisture Content:

low= 0.061 best estimate= 0.148 high= 0.24

Capillary Zone Moisture Content: 0.332 Height of Capillary Rise: 0.375 [m]

Soil-Gas Flow Rate into Building: 5 [L/min]

BUILDING PROPERTIES

Building Type: Slab-on-Grade Air Exchange Rate: 0.25[hr^{-1}]

Building Mixing Height: 2.44[m] Building Footprint Area: 100[m^2]

Subsurface Foundation Area: 106[m^2] Building Crack Ratio: 0.00038[unitless]

Foundation Slab Thickness: 0.1[m]

EXPOSURE PARAMETERS

Exposure Duration: carcinogens 30 [years] non-carcinogens: 30 [years]

Exposure Frequency: carcinogens 350 [days/year] non-carcinogens: 365 [days/year]

Averaging Time: carcinogens 70 [years] non-carcinogens: 30 [years]

JOHNSON & ETTINGER SIMULATION RESULTS

Effective Diffusion Coefficient (D^T_{eff}): 0.001161[cm^2/s]

Ground Water to Indoor Air Attenuation Factor (α_{GW}) = 0.00009832

[1]Low Indoor Air Prediction: 1.757 [$\mu g/m^3$] or 0.5502 [ppbv]

Cancer Risk of this concentration: 5.631e-6 Hazard Risk of this concentration: 0.

Best Estimate Indoor Air Prediction: 3.115[$\mu g/m^3$] or 0.9757 [ppbv]

Cancer Risk of this concentration: 9.985e-6 Hazard Risk of this concentration: 0.

[2]High Indoor Air Prediction: 3.576[μ g/m^3] or 1.120 [ppbv]

Cancer Risk of this concentration: 1.146e-5 Hazard Risk of this concentration: 0.

Based on parameter analysis: Advection is the dominant mechanism across foundation. Diffusion through soil is the overall rate-limiting process for the subsurface to indoor-air pathway.

[1]"Low Prediction" concentrations produced with HIGHEST moisture content and DEEPEST depth to contamination.

[2]"High Prediction" concentrations produced with LOWEST moisture content and SHALLOWEST depth to contamination.

INDOOR AIR SIMULATION RESULTS - TOLUENE
Screening-Level Johnson and Ettinger Model

Site Name: CORCO

Report Generated From: http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

Type of sample: GROUND WATER Concentration = 15500[ppb-water]

Depth to ground water table: 23.75ft +/- 2ft

Average soil/ground water temperature: 77F

CHEMICAL PROPERTIES

Chemical of Concern: Toluene CAS Number: 108883

Molecular Weight: 92.14 [g/mole] Henrys Constant: 0.2707454 [unitless]

Diffusivity in Air: 8.700e-2 [cm^2/sec] Diffusivity in Water: 8.600e-6 [cm^2/sec]

Unit Risk Factor: 0 [(μ g/m^3)$^{-1}$] Reference Concentration: 0.4 [mg/m^3]

SOIL PROPERTIES

Soil Type: Loam Total Porosity: 0.399

Unsaturated Zone Moisture Content:

low= 0.061 best estimate= 0.148 high= 0.24

Capillary Zone Moisture Content: 0.332 Height of Capillary Rise: 0.375 [m]

Soil-Gas Flow Rate into Building: 5 [L/min]

BUILDING PROPERTIES

Building Type: Slab-on-Grade Air Exchange Rate: 0.25[hr^{-1}]

Building Mixing Height: 2.44[m] Building Footprint Area: 100[m^2]

Subsurface Foundation Area: 106[m^2] Building Crack Ratio: 0.00038[unitless]

Foundation Slab Thickness: 0.1[m]

EXPOSURE PARAMETERS

Exposure Duration: carcinogens 30 [years] non-carcinogens: 30 [years]

Exposure Frequency: carcinogens 350 [days/year] non-carcinogens: 365 [days/year]

Averaging Time: carcinogens 70 [years] non-carcinogens: 30 [years]

JOHNSON & ETTINGER SIMULATION RESULTS

Effective Diffusion Coefficient (D^T_{eff}): 0.001126[cm^2/s]

Ground Water to Indoor Air Attenuation Factor (α_{GW}) = 0.0000954

[1]Low Indoor Air Prediction: 227.5 [μ g/m^3] or 60.42 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 0.5689

Best Estimate Indoor Air Prediction: 400.3[µ g/m^3] or 106.3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.001

[2]High Indoor Air Prediction: 458.3[µ g/m^3] or 121.7 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.146

Based on parameter analysis: Advection is the dominant mechanism across foundation. Diffusion through soil is the overall rate-limiting process for the subsurface to indoor-air pathway.

[1]"Low Prediction" concentrations produced with HIGHEST moisture content and DEEPEST depth to contamination.

[2]"High Prediction" concentrations produced with LOWEST moisture content and SHALLOWEST depth to contamination.

INDOOR AIR SIMULATION RESULTS - ETHYLBENZENE
Screening-Level Johnson and Ettinger Model

Site Name: CORCO

Report Generated From: http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

Type of sample: GROUND WATER Concentration = 850[ppb-water]

Depth to ground water table: 23.75ft +/- 2ft

Average soil/ground water temperature: 77F

CHEMICAL PROPERTIES

Chemical of Concern: Ethylbenzene CAS Number: 100414

Molecular Weight: 106.17 [g/mole] Henrys Constant: 0.3213063 [unitless]

Diffusivity in Air: 7.500e-2 [cm^2/sec] Diffusivity in Water: 7.800e-6 [cm^2/sec]

Unit Risk Factor: 0.0000011 [$(\mu\ g/m^3)^{-1}$] Reference Concentration: 1 [mg/m^3]

SOIL PROPERTIES

Soil Type: Loam Total Porosity: 0.399

Unsaturated Zone Moisture Content:

low= 0.061 best estimate= 0.148 high= 0.24

Capillary Zone Moisture Content: 0.332 Height of Capillary Rise: 0.375 [m]

Soil-Gas Flow Rate into Building: 5 [L/min]

BUILDING PROPERTIES

Building Type: Slab-on-Grade Air Exchange Rate: 0.25[hr^{-1}]

Building Mixing Height: 2.44[m] Building Footprint Area: 100[m^2]

Subsurface Foundation Area: 106[m^2] Building Crack Ratio: 0.00038[unitless]

Foundation Slab Thickness: 0.1[m]

EXPOSURE PARAMETERS

Exposure Duration: carcinogens 30 [years] non-carcinogens: 30 [years]

Exposure Frequency: carcinogens 350 [days/year] non-carcinogens: 365 [days/year]

Averaging Time: carcinogens 70 [years] non-carcinogens: 30 [years]

JOHNSON & ETTINGER SIMULATION RESULTS

Effective Diffusion Coefficient (D^T_{eff}): 0.0009642[cm^2/s]

Ground Water to Indoor Air Attenuation Factor (α_{GW}) = 0.00008194

[1]Low Indoor Air Prediction: 12.74 [$\mu\ g/m^3$] or 2.936 [ppbv]

Cancer Risk of this concentration: 5.759e-6 Hazard Risk of this concentration: 0.01274

Best Estimate Indoor Air Prediction: 22.38[$\mu\ g/m^3$] or 5.157 [ppbv]

Cancer Risk of this concentration: 1.012e-5 Hazard Risk of this concentration: 0.02238

[2]High Indoor Air Prediction: 25.61[μ g/m³] or 5.900 [ppbv]

Cancer Risk of this concentration: 1.157e-5 Hazard Risk of this concentration: 0.02561

Based on parameter analysis: Advection is the dominant mechanism across foundation. Diffusion through soil is the overall rate-limiting process for the subsurface to indoor-air pathway.

[1]"Low Prediction" concentrations produced with HIGHEST moisture content and DEEPEST depth to contamination.

[2]"High Prediction" concentrations produced with LOWEST moisture content and SHALLOWEST depth to contamination.

INDOOR AIR SIMULATION RESULTS – o-XYLENE
Screening-Level Johnson and Ettinger Model

Site Name: CORCO

Report Generated From: http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

Type of sample: GROUND WATER Concentration = 340000[ppb-water]

Depth to ground water table: 23.75ft +/- 2ft

Average soil/ground water temperature: 77F

CHEMICAL PROPERTIES

Chemical of Concern: o-Xylene CAS Number: 95476

Molecular Weight: 106.17 [g/mole] Henrys Constant: 0.2116218 [unitless]

Diffusivity in Air: 8.700e-2 [cm^2/sec] Diffusivity in Water: 1.000e-5 [cm^2/sec]

Unit Risk Factor: 0 [(μ g/m^3)$^{-1}$] Reference Concentration: 7 [mg/m^3]

SOIL PROPERTIES

Soil Type: Loam Total Porosity: 0.399

Unsaturated Zone Moisture Content:

low= 0.061 best estimate= 0.148 high= 0.24

Capillary Zone Moisture Content: 0.332 Height of Capillary Rise: 0.375 [m]

Soil-Gas Flow Rate into Building: 5 [L/min]

BUILDING PROPERTIES

Building Type: Slab-on-Grade Air Exchange Rate: 0.25[hr^{-1}]

Building Mixing Height: 2.44[m] Building Footprint Area: 100[m^2]

Subsurface Foundation Area: 106[m^2] Building Crack Ratio: 0.00038[unitless]

Foundation Slab Thickness: 0.1[m]

EXPOSURE PARAMETERS

Exposure Duration: carcinogens 30 [years] non-carcinogens: 30 [years]

Exposure Frequency: carcinogens 350 [days/year] non-carcinogens: 365 [days/year]

Averaging Time: carcinogens 70 [years] non-carcinogens: 30 [years]

JOHNSON & ETTINGER SIMULATION RESULTS

Effective Diffusion Coefficient (D^T_{eff}): 0.001157[cm^2/s]

Ground Water to Indoor Air Attenuation Factor (α_{GW}) = 0.00009795

[1]Low Indoor Air Prediction: 3.962e3 [μ g/m^3] or 912.9 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 0.5659

Best Estimate Indoor Air Prediction: 7.048e3[μ g/m^3] or 1.624e3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.007

[2]High Indoor Air Prediction: 8.100e3[μ g/m³] or 1.866e3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.157

Based on parameter analysis: Advection is the dominant mechanism across foundation. Diffusion through soil is the overall rate-limiting process for the subsurface to indoor-air pathway.

[1]"Low Prediction" concentrations produced with HIGHEST moisture content and DEEPEST depth to contamination.

[2]"High Prediction" concentrations produced with LOWEST moisture content and SHALLOWEST depth to contamination.

INDOOR AIR SIMULATION RESULTS – m-XYLENE
Screening-Level Johnson and Ettinger Model

Site Name: CORCO

Report Generated From: http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

Type of sample: GROUND WATER Concentration = 305000[ppb-water]

Depth to ground water table: 23.75ft +/- 2ft

Average soil/ground water temperature: 77F

CHEMICAL PROPERTIES

Chemical of Concern: m-Xylene CAS Number: 108383

Molecular Weight: 106.17 [g/mole] Henrys Constant: 0.2992879 [unitless]

Diffusivity in Air: 7.000e-2 [cm^2/sec] Diffusivity in Water: 7.800e-6 [cm^2/sec]

Unit Risk Factor: 0 [(μ g/m^3)$^{-1}$] Reference Concentration: 7 [mg/m^3]

SOIL PROPERTIES

Soil Type: Loam Total Porosity: 0.399

Unsaturated Zone Moisture Content:

low= 0.061 best estimate= 0.148 high= 0.24

Capillary Zone Moisture Content: 0.332 Height of Capillary Rise: 0.375 [m]

Soil-Gas Flow Rate into Building: 5 [L/min]

BUILDING PROPERTIES

Building Type: Slab-on-Grade Air Exchange Rate: 0.25[hr^{-1}]

Building Mixing Height: 2.44[m] Building Footprint Area: 100[m^2]

Subsurface Foundation Area: 106[m^2] Building Crack Ratio: 0.00038[unitless]

Foundation Slab Thickness: 0.1[m]

EXPOSURE PARAMETERS

Exposure Duration: carcinogens 30 [years] non-carcinogens: 30 [years]

Exposure Frequency: carcinogens 350 [days/year] non-carcinogens: 365 [days/year]

Averaging Time: carcinogens 70 [years] non-carcinogens: 30 [years]

JOHNSON & ETTINGER SIMULATION RESULTS

Effective Diffusion Coefficient (D^T_{eff}): 0.0009068[cm^2/s]

Ground Water to Indoor Air Attenuation Factor (α_{GW}) = 0.00007713

[1]Low Indoor Air Prediction: 3.994e3 [μ g/m^3] or 920.3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 0.5705

Best Estimate Indoor Air Prediction: 7.041e3[μ g/m^3] or 1.622e3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.006

[2]High Indoor Air Prediction: 8.066e3[μ g/m^3] or 1.859e3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.152

Based on parameter analysis: Advection is the dominant mechanism across foundation. Diffusion through soil is the overall rate-limiting process for the subsurface to indoor-air pathway.

[1]"Low Prediction" concentrations produced with HIGHEST moisture content and DEEPEST depth to contamination.

[2]"High Prediction" concentrations produced with LOWEST moisture content and SHALLOWEST depth to contamination.

INDOOR AIR SIMULATION RESULTS – p-Xylene
Screening-Level Johnson and Ettinger Model

Site Name: CORCO

Report Generated From: http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

Type of sample: GROUND WATER Concentration = 267000[ppb-water]

Depth to ground water table: 23.75ft +/- 2ft

Average soil/ground water temperature: 77F

CHEMICAL PROPERTIES

Chemical of Concern: p-Xylene CAS Number: 106423

Molecular Weight: 106.17 [g/mole] Henrys Constant: 0.3123359 [unitless]

Diffusivity in Air: 7.690e-2 [cm^2/sec] Diffusivity in Water: 8.440e-6 [cm^2/sec]

Unit Risk Factor: 0 [$(\mu g/m^3)^{-1}$] Reference Concentration: 7 [mg/m^3]

SOIL PROPERTIES

Soil Type: Loam Total Porosity: 0.399

Unsaturated Zone Moisture Content:

low= 0.061 best estimate= 0.148 high= 0.24

Capillary Zone Moisture Content: 0.332 Height of Capillary Rise: 0.375 [m]

Soil-Gas Flow Rate into Building: 5 [L/min]

BUILDING PROPERTIES

Building Type: Slab-on-Grade Air Exchange Rate: 0.25[hr^{-1}]

Building Mixing Height: 2.44[m] Building Footprint Area: 100[m^2]

Subsurface Foundation Area: 106[m^2] Building Crack Ratio: 0.00038[unitless]

Foundation Slab Thickness: 0.1[m]

EXPOSURE PARAMETERS

Exposure Duration: carcinogens 30 [years] non-carcinogens: 30 [years]

Exposure Frequency: carcinogens 350 [days/year] non-carcinogens: 365 [days/year]

Averaging Time: carcinogens 70 [years] non-carcinogens: 30 [years]

JOHNSON & ETTINGER SIMULATION RESULTS

Effective Diffusion Coefficient (D^T_{eff}): 0.0009929[cm^2/s]

Ground Water to Indoor Air Attenuation Factor (α_{GW}) = 0.00008434

[1]Low Indoor Air Prediction: 3.997e3 [$\mu g/m^3$] or 921.1 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 0.5710

Best Estimate Indoor Air Prediction: 7.033e3[$\mu g/m^3$] or 1.621e3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.005

[2]High Indoor Air Prediction: 8.052e3[μ g/m^3] or 1.855e3 [ppbv]

Cancer Risk of this concentration: 0. Hazard Risk of this concentration: 1.150

Based on parameter analysis: Advection is the dominant mechanism across foundation. Diffusion through soil is the overall rate-limiting process for the subsurface to indoor-air pathway.

[1]"Low Prediction" concentrations produced with HIGHEST moisture content and DEEPEST depth to contamination.

[2]"High Prediction" concentrations produced with LOWEST moisture content and SHALLOWEST depth to contamination.

Appendix E - USEPA NAPL-ADV Model

Commonwealth Oil and Refining Company
Route 127, Peñuelas, Puerto Rico
Vapor Intrusion Screening

EPA ID #: PRD091017228

NAPL-ADV Ver. 2.0 (02/03)
Requires the SOLVER Add-in.

Reset to Defaults — Restore Defaults
Done — Execute Model

RESULTS

	ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil concentration, C_R (mg/kg)	Chemical	Time-averaged building concentration ($\mu g/m^3$)	Incremental cancer risk (unitless)	Route-to-route extrap. (X)	Hazard quotient (unitless)	Route-to-route extrap. (X)
1.	71432	69	Benzene	3.75E+00	7.2E-06		NA	
2.	108883	22	Toluene	1.22E+00	NA		2.1E-03	
3.	100414	79	Ethylbenzene	4.32E+00	1.2E-06		3.0E-03	
4.	95476	245	o-Xylene	1.34E+01	NA		1.3E-03	X
5.	108383	245	m-Xylene	1.34E+01	NA		1.3E-03	X
6.	106423	245	p-Xylene	1.34E+01	NA		1.3E-03	X
7.			CAS No. not found	0.00E+00	0.0E+00		0.0E+00	
8.			CAS No. not found	0.00E+00	0.0E+00		0.0E+00	
9.			CAS No. not found	0.00E+00	0.0E+00		0.0E+00	
10.			CAS No. not found	0.00E+00	0.0E+00		0.0E+00	
				TOTALS:	8.3E-06		9.0E-03	

TIME-STEP PARAMETERS

ENTER Initial time-step, δt (days)	ENTER Maximum change in mass, ΔM_i^{max} (%)	ENTER Minimum change in mass, ΔM_i^{min} (%)
4	10	5

MORE ↓

MORE →

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Width of contamination, W_C (cm)	ENTER Length of contamination, L_C (cm)	ENTER Thickness of contamination, H_C (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C (Enter value or 0) h_C (cm)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
10.24	723	1524	4267	1	25	162	162	399			1.00E-08

Totals must add up to value of L_t (cell C30)

MORE ↓

MORE →

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
	1.75	0.25	0.15	0.005		1.75	0.25	0.15	0.005		1.43	0.3	0.2	0.004

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	4267	1524	244	0.1	0.5	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	25	25	250

END

On-Site Environmental, Inc.